FOREST SERVICE RESEARCH PAPER ITF - 7
MAY 1968

SHAPING AND PLANING CHARACTERISTICS OF PLANTATION-GROWN MAHOGANY AND TEAK

BY
E. D. MALDONADO AND R. S. BOONE

INSTITUTE OF TROPICAL FORESTRY
RIO PIEDRAS, PUERTO RICO

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

RESUMEN

La capacidad para el trabajo a máquina es una propiedad crítica de las maderas que se usan para hacer muebles y trabajos de ebanistería. Este estudio informa sobre algunas características del trabajo a máquina de la caoba y la teca cultivadas en plantaciones en Puerto Rico. También está incluída la caoba de hoja pequeña (Indias Occidentales) de Santa Cruz, Islas Vírgenes de los Estados Unidos de América. El moldeado y el cepillado se seleccionaron para evaluación ya que estas operaciones son decisivas en las partes expuestas de los muebles. Se probó la caoba que crece en los bosques naturales de México, Honduras y Perú; la teca de Burma; y dos maderas de las zonas templadas, ocozal de los Estados Unidos y el abedul de Canadá, para compararlas con las maderas cultivadas localmente.

Muestras de la caoba de hoja pequeña de Santa Cruz resultaron ser superiores en cuanto a las propiedades de cepillado y moldeado a aquéllas de todas las demás maderas probadas. En moldeado la caoba de hoja grande de la plantación de Río Abajo y el híbrido de la plantación Harvey calificaron tan buenos como las caobas importadas o hasta mejores. En general, todas las maderas se comportaron bien en cepillado. La teca de plantaciones locales resultó ser tan buena en moldeado como la teca de los bosques naturales de Burma. Los defectos del cepillado en la teca no fueron significativamente diferentes excepto por la fibra desgarrada que fué más severa en la madera de plantaciones. La caoba de plantaciones de crecimiento rápido no es significativamente diferente en densidad a los troncos de la de crecimiento lento. La calidad del moldeado se correlaciona sólo levemente con el peso específico y el ritmo de crecimiento.

SHAPING AND PLANING CHARACTERISTICS OF PLANTATION-GROWN MAHOGANY AND TEAK

By
E. D. Maldonado and R. S. Boone
Institute of Tropical Forestry, Río Piedras, Puerto Rico[1/]

SUMMARY

Machinability is a critical property of woods that are used primarily in furniture and cabinet work. This study reports on some machining characteristics of Puerto Rico plantation-grown mahogany and teak. Also included is small-leaf (West Indies) mahogany from St. Croix, U.S. Virgin Islands. Shaping and planing were chosen for evaluation since these operations are decisive in exposed furniture parts. Mahogany from forest-grown stands in Mexico, Honduras, and Perú; teak from Burma; and two temperate zone timbers, sweetgum from the United States and birch from Canada, were tested for comparison to the locally-grown woods.

Samples of small-leaf mahogany from St. Croix proved superior in shaping and planing properties to those of all other woods tested. In shaping, bigleaf mahogany from the Río Abajo plantation and the hybrid from Harvey rated as good as the imported mahoganies or even better. In general, all the mahoganies performed well in planing. Local plantation-grown teak proved, in shaping, to be as good as forest-grown teak from Burma. Planing defects in teak were not significantly different except for torn grain which was more severe in the plantation wood. Fast-grown plantation mahogany is not significantly different in density from slow-grown stems. Shaping quality is only weakly correlated with specific gravity and growth rate.

1/ In cooperation with the University of Puerto Rico

INTRODUCTION

Bigleaf mahogany (Swietenia macrophylla King) is the principal wood utilized by the furniture and millwork industry of Puerto Rico, some six million board feet being imported annually (20). Local recognition of the value of this and other well known tropical timbers for this purpose led to reforestation with bigleaf mahogany, small-leaf or West Indies mahogany (Swietenia mahagoni Jacq.), and teak (Tectona grandis L.) in Puerto Rico and the Virgin Islands. The first logs from these young plantations are becoming available for comparison of their qualities with those of imported timber.

Wood properties of plantation-grown versus forest-grown trees have been extensively studied. Elliot (8) reports that in Australia variations in the wood of plantation or second-growth trees are no greater than is normally found in forest-grown trees of the same species. He concludes that wood from plantation-grown eucalypts, if properly sawed and sessoned, is as well suited for manufacturing as is wood of the same species from old-growth forests. Other studies on eucalypts generally support this conclusion (5,9,10).

The physical and mechanical properties of plantation-grown mahogany have been determined (7). Compared to forest-grown wood from several sources, the plantation material is slightly lower in density and bending strength. Crushing strength is markedly lower. However, plantation-grown mahogany is comparable in tension across the grain, and superior in hardness, compression perpendicular to the grain, and shear. Investigations of plantation and forest-grown teak in Thailand and Burma indicate no differences, except in ash content (1,19,21).

Information on machinability is desirable in addition to data on mechanical properties for woods that are converted principally for cabinet and furniture work. Davis (6) states that, for such uses, surface smoothness and facility with which woods can be worked may be the most important of all properties. Unless a wood machines fairly well and with moderate ease, it is not economically suitable for furniture production, regardless of its other virtues.

This study was undertaken to evaluate the machining characteristics of local plantation-grown mahogany and teak. Some samples of mahogany from forest stands in Mexico, Honduras, and Perú; teak from Burma; sweetgum from the United States; and birch from Canada were also tested for comparative purposes. Response to shaping and planing were chosen for evaluation since these operations are common and also critical in exposed furniture parts.

Specifically the following were investigated:

1. Machining characteristics (shaping and planing) of plantation-grown mahogany and teak as compared to forest-grown wood.

2. The relationship of specific gravity and growth rate to machining quality of plantation mahogany.

3. The relationship between growth rate and specific gravity of plantation mahogany.

MATERIALS AND METHODS

Description of species sources and sites

Bigleaf mahogany grown at the Bisley, Río Abajo, and Harvey plantations was selected for testing. The Harvey trees have an intermediate leaf type and are believed to be a hybridization of bigleaf and small-leaf mahoganies (2,15). Included also for evaluation was wood of local plantation-grown teak established at Patillas and Río Abajo, and wood from trees which regenerated naturally near early plantings of small-leaf mahogany in St. Croix, U.S. Virgin Islands. Seed sources and site features are described in table 1.

For comparison, samples of commercial lumber shipments of bigleaf mahogany from forest-grown trees in Mexico, Honduras, and Perú were tested as well as teak from Burma, yellow birch (*Betula alleghaniensis* Britton) from Canada, and sweetgum (*Liquidambar styraciflua* L.) grown in the southeastern United States.

Selection of sample material and sample size

The number of trees, diameter ranges, and age of mahogany tested are also given in table 1. Patillas and Río Abajo teak samples were obtained from random boards selected at a local sawmill. The imported mahogany, birch, sweetgum, and teak were supplied by lumber dealers. Nominal, flat-grain, air-dry boards free of knots and drying defects were used in the tests. Specific gravity of the forest-grown mahogany ranged from 0.52 to 0.56, and for plantation-grown wood from 0.46 to 0.70, air-dry volume and weight at 12 percent moisture content (table 2).

The tests began with 50 specimens for each of the machining operations. After evaluation of four sources (Perú, Mexico, Honduras, and Bisley), calculations were made to determine minimum sample size. Twenty-five specimens were found adequate for 95 percent confidence limits. In testing the remaining

Table 1.--Tree and site description of mahogany and teak study material from Puerto Rico and St. Croix, U. S. Virgin Islands

Species and Stand	Seed Source	Age	Trees Tested		Soil[1]	Elevation	Mean Annual rainfall	Mean Annual temperature
			No.	Dia. Range				
		Yrs.		In.		Ft.	In.	°F.
Bigleaf mahogany (Bisley)	Panama	24	32	7.9-18.0	Catalina stony clay	1000	135	75
Bigleaf mahogany (Río Abajo)	Venezuela	26	12	8.3-18.0	Cialitos clay	600	80	75
Hybrid mahogany[2] (Harvey)	St. Croix	33	12	8.5-18.0	Catalina stony clay	750	97	76
Small-leaf mahogany[3] (St. Croix)	St. Croix	33	12	8.5-19.5	Aguilita gravelly clay loam	500	38	76
Teak (Patillas)	Trinidad	24	--[4]	8 - 12	Múcara silty clay loam	400	70	76
Teak (Río Abajo)	Trinidad	24	--[4]	8 - 12	Tanamá stony clay	600	80	75

1/ R.C. Roberts, et.al,1942. Soil survey of Puerto Rico; U.S.D.A.: Bureau of Plant Industry,Series 1936, No.8, 503 pp.
2/ Possible hybrid bigleaf X small-leaf.
3/ Established by natural seeding from earlier plantings.
4/ Boards randomly selected from stock, number of trees not known.

Table 2.--Specific gravity of woods tested

Species and Source	Specific Gravity[1]
Mahogany	
Forest-grown	
Perú	.56
Mexico	.54
Honduras	.52
Plantation-grown	
St. Croix[2]	.70
Harvey (hybrid)	.55
Río Abajo	.49
Bisley	.46
Teak	
Forest-grown	
Burma	.65
Plantation-grown	
Río Abajo	.65
Patillas	.62
Temperate zone woods	
Birch (Canada)	.68
Sweetgum (U.S.A.)	.59

1/ Based on air-dry weight and air-dry volume adjusted to 12 percent moisture content.

2/ Established by natural seeding from earlier plantings of *Swietenia mahagoni* Jacq.

species and sources, 25 specimens were used. For those comparisons between and within trees, 25 specimens were selected per tree.

Grading

Smoothness of cut was selected as the critical factor in judging the machinability of the different woods. Frequency and severity of cutting defects were graded on a numerical scale as follows: grade 1 was considered as excellent (defect free); 2 - good; 3 - fair; 4 - poor; and 5 - very poor. To facilitate comparisons, the percentages of specimens grading good to excellent were calculated. Moreover, a rating obtained by averaging grades of test samples was obtained. The lower this rating (the nearer it approaches 1.0), the fewer the defects and the better the machining quality.

Defects evaluated in the shaping and planing tests are defined as follows (6):

Raised grain -- a roughened condition of the surface of the piece in which part of the structural elements are raised above the general surface but not torn loose from it (figure 1A).

Fuzzy grain -- this consists of small particles, groups of small particles, or groups of fibers that do not sever cleanly in machining, but stand up above the general level of the surface (figure 1B).

Torn grain -- a chipped surface where short particles are broken out below the line of cut (figure 1C).

Chip marks -- (planing only) shallow dents in the surface caused by shavings that have clung to the knives instead of passing off in the exhaust system (figure 1D).

Mahogany and teak specimens were coded, mixed, and machined and graded in random order, to minimize bias. To insure sharpness during all tests, knives were changed frequently.

Planing tests

Planing may be defined as the peripheral milling of wood to smooth one or more surfaces of the workpiece and to bring it to a prescribed thickness (14). Normally the feed and grain are so oriented that the knives cut parallel to the grain. A 4 by 12-inch single surface planer was used, with a 3-knife cutterhead revolving at 4500 r.p.m. making 60 cuts per inch with a cutting angle of 29°.

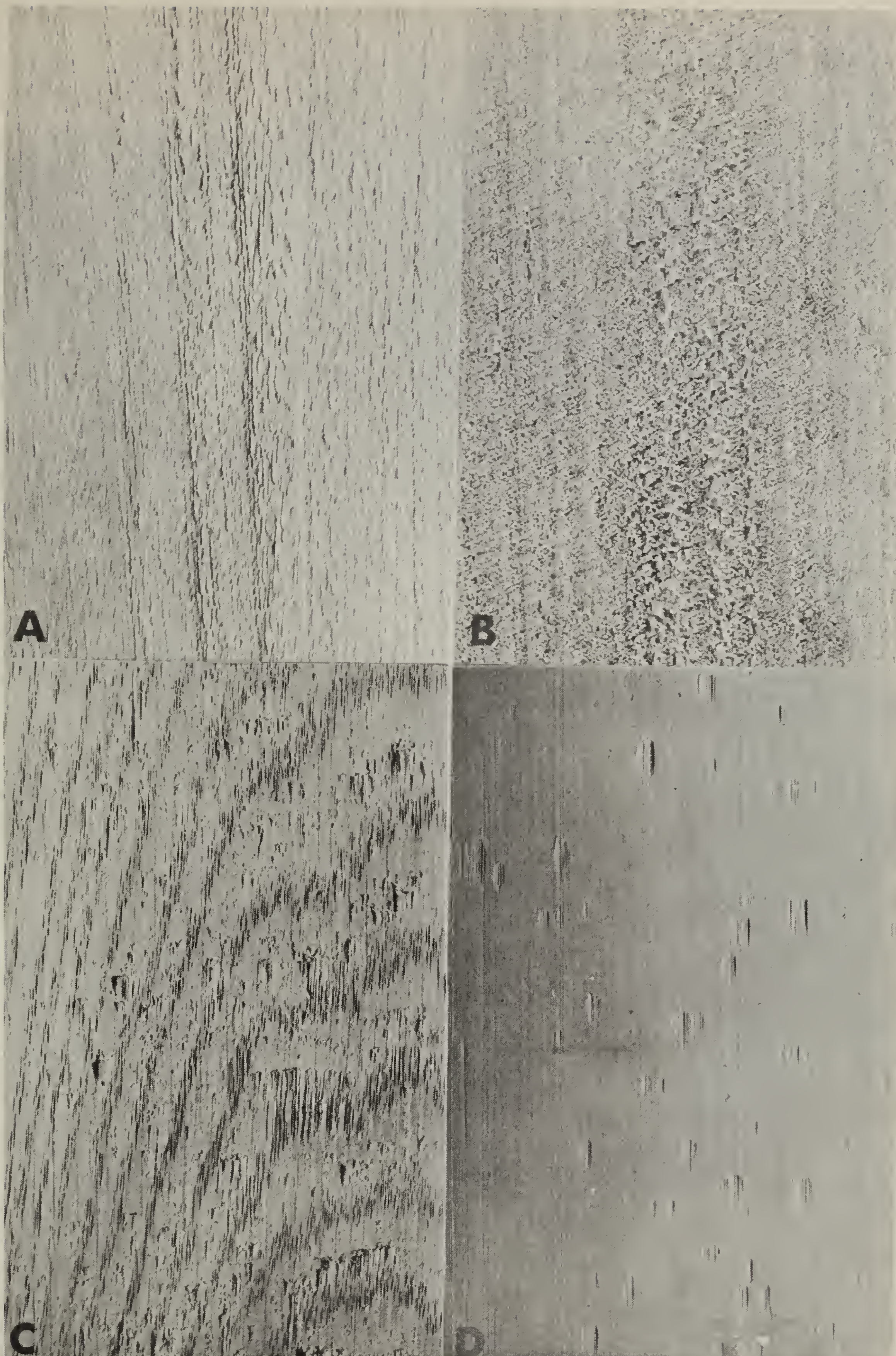

Figure 1.--Machining defects evaluated in the shaping and planing tests: A, raised grain; B, fuzzy grain; C, torn grain; D, chip marks.

Test specimens were 1 by 4 by 36 inches, clear, flat grained, and air dried to about 14 percent moisture content. The planer was set to make a 1/16-inch cut.

Shaping tests

Shaping is a peripheral milling process used to cut an edge profile or edge pattern on a workpiece (14). The machine used in these tests was a belt driven, single-spindle shaper with a 2 1/2-inch diameter cutter operated at 11,000 r.p.m. by a 1 1/2-horsepower electric motor (figure 2). Machines of this small size are common in furniture plants in Puerto Rico.

The flat-grained test specimens were 7/8-inch thick by 3 by 12 inches, and air dried to a moisture content of about 14 percent. Each specimen was bored for mounting in a jig (figure 2) and roughed out to the desired pattern with a band saw. The shaping operation involved cutting a profile along the grain, at angles with the grain, and across the grain.

RESULTS AND DISCUSSION

Comparative planing quality

The relative planing quality of the woods tested (table 3) is based on percentages of samples rated good to excellent (grades 1 and 2). Average ratings are also presented in table 3. Sweetgum was not evaluated in this test. Ratings for the four individual defects (raised grain, torn grain, fuzzy grain, and chip marks) are shown in table 4 (Appendix).

The data in table 3 indicate that small-leaf mahogany tested from St. Croix is superior in planing to the hybrid or bigleaf mahogany regardless of source. The teak from Burma also has excellent planing characteristics. In general, all the woods performed well.

Whether or not the differences shown are significant has been determined and results of analyses of variance are given in tables 5 and 6 (Appendix). The following conclusions can be made:

1. Raised grain -- there are no significant differences between species or sources.

2. Fuzzy grain -- plantation mahogany is as good as the three commercial mahogany sources or superior to them. There are no significant differences between the plantation-grown teak and the Burmese source. All of the teak sources and birch are superior to the imported mahoganies.

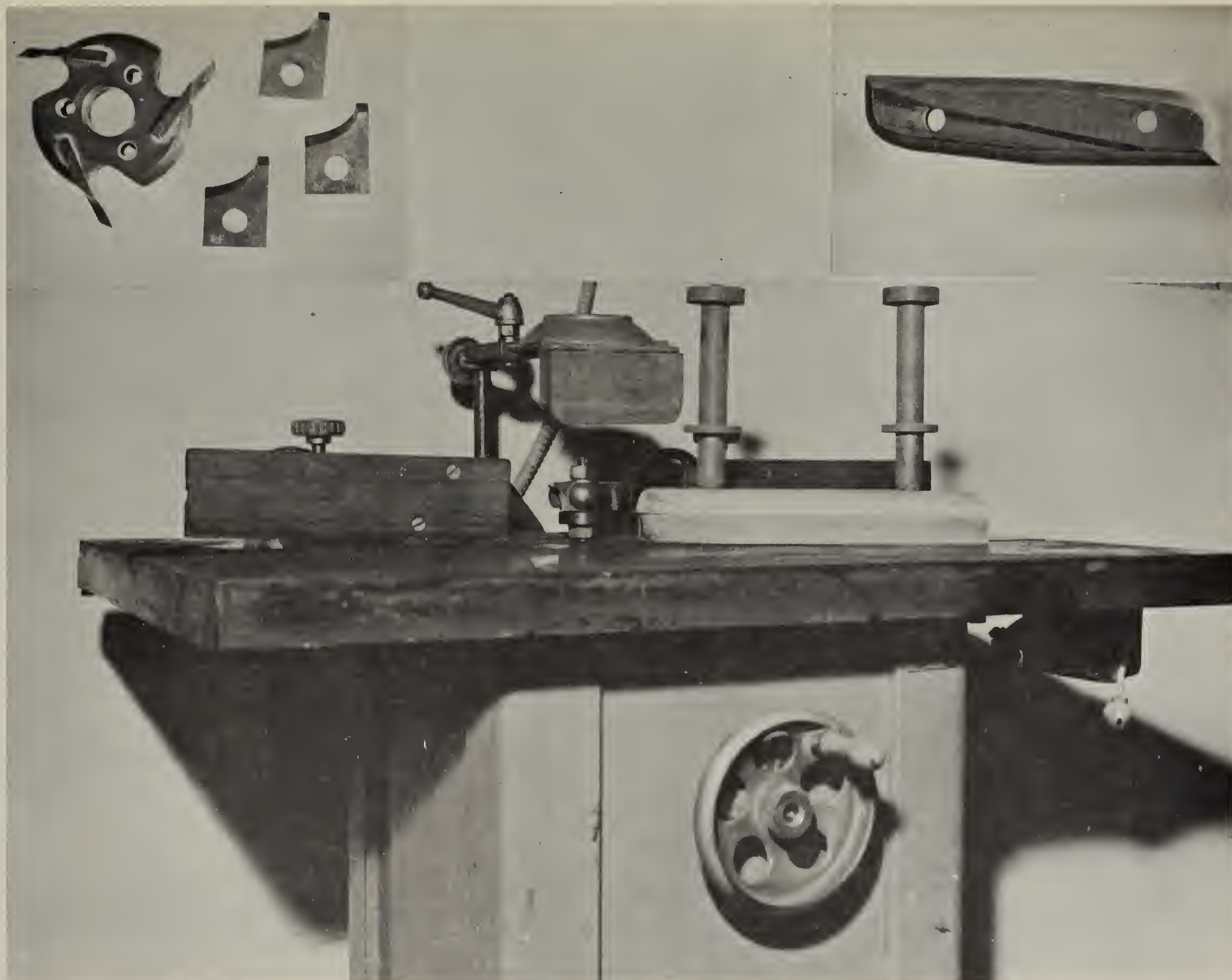

Figure 2.--Single-spindle shaper and roughed out specimen mounted in jig. Insets: cutterhead and knife profile; machined test specimen.

Table 3.--Ratings of planing and shaping defects

Species and Source	Planing: Good to excellent pieces	Planing: Average rating[1]	Shaping: Good to excellent pieces	Shaping: Average rating[1]
	Pct.		Pct.	
Mahogany				
Forest-grown				
Mexico	74	1.2	21	2.6
Peru	44	1.6	11	2.7
Honduras	43	1.6	7	3.0
Plantation-grown				
St. Croix[2]	92	1.1	92	1.3
Harvey (hybrid)	64	1.4	67	1.7
Rio Abajo	64	1.4	57	1.8
Bisley	64	1.4	2	3.3
Teak				
Forest-grown				
Burma	92	1.2	79	1.3
Plantation-grown				
Patillas	65	1.3	58	1.6
Rio Abajo	64	1.4	46	1.7
Temperate zone woods				
Birch (Canada)	52	1.4	71	1.6
Sweetgum (U.S.A.	--	--	38	1.8

1/ Based on a 1-5 scale with 1 - defect free, and 5 - very poor. Values are averages of all machining defects i.e., fuzzy grain, torn grain, etc.
2/ Established by natural seeding from earlier plantings of *Swietenia mahagoni* Jacq.

3. Torn grain -- generally the plantation-grown mahoganies are not different than the outside commercial sources. In the teak from Burma this defect is less severe than in the two plantation sources.

4. Chip marks -- generally there are no significant differences between the several woods for this minor defect, with the exception of mahoganies from Bisley and Honduras which are rated inferior.

Comparative shaping quality

As for the planing evaluations, the relative quality of the 12 woods tested in shaping (table 3) is based on percentages of samples rated good to excellent (grades 1 and 2). No raised grain was noted. The ratings are based on presence and severity of fuzzy and torn grain on cuts made parallel and across the grain. Average grades are also presented in table 3. Ratings for individual defects i.e., torn end grain, fuzzy end grain, etc., are shown in table 7 (Appendix).

The ratings in table 3 show that small-leaf mahogany from St. Croix and its presumed hybrid from the Harvey plantation are superior in shaping quality to bigleaf mahogany, regardless of source.

Whether or not the differences shown are significant has been determined and results of analyses of variance are given in tables 8 and 9 (Appendix). From these the following conclusions can be drawn:

1. The small-leaf mahogany samples from St. Croix proved superior to the other mahogany sources tested.

2. Bigleaf mahogany from the Río Abajo plantation and the hybrid from the Harvey plantation have comparable shaping quality.

3. The bigleaf mahogany imported from Mexico, Perú, and Honduras, as well as plantation-grown wood from Bisley, have ratings inferior to the other mahoganies.

4. The teak from the two local plantations (Río Abajo and Patillas) is not significantly different in shaping characteristics from the Burma teak.

Davis (6) found that, in both planing and shaping, mahogany had more defect-free pieces than birch or sweetgum. We found that five of our seven mahogany sources rated better than birch in planing. In the shaping tests, only one mahogany source ranked higher than birch, and three of seven rated better than sweetgum (table 3).

Relationship of Specific Gravity and Growth Rate with Machining Quality

Specific gravity

Small blocks for specific gravity determinations (immersion method) were obtained from the shaping test specimens. At least ten samples were selected as representative for each species and source. Specific gravity based on air-dry weight and volume adjusted to a 12 percent moisture content is given in table 2. The heaviest of the woods tested was small-leaf mahogany from St. Croix and the lightest was bigleaf from the Bisley plantation.

Specific gravities of the mahoganies sampled are generally within the range of much of the mahogany reaching the market. Longwood (18) reports forest-grown bigleaf mahogany to have an air-dry specific gravity range of 0.50 to 0.59. Plantation-grown bigleaf mahogany is indicated to have an air-dry specific gravity of 0.50. Our small-leaf mahogany and teak density values are somewhat lower than those reported by Longwood (18).

Specific gravity has been shown to vary with position in the tree, both in height from the ground and radially (3,4,23). Briscoe, *et al*. (3) investigating variations in specific gravity of bigleaf mahogany in Puerto Rico found: 1) specific gravity was high at the base, dropped to a minimum at eight feet, then increased upwards to near the base of the crown; 2) the wood immediately surrounding the pith was the lightest and specific gravity increased outwards.

Relationship between specific gravity and shaping quálity

The samples from the Bisley and Río Abajo plantations are quite similar in specific gravity (see table 2). Yet in relative shaping, the Río Abajo source is the best of the bigleaf mahoganies with 57 percent of the pieces rating good to excellent as compared to Bisley with only 2 percent (table 3).

Regression analyses relating specific gravity and shaping quality were made for mahogany from the Río Abajo and Bisley plantations. Ninety-six specimens from each location representing all quality groups were used. Average specific gravity of the Río Abajo material was 0.49, ranging from 0.42 to 0.63. Wood from Bisley averaged 0.46, varying from 0.37 to 0.58. Each site was analyzed separately followed by an analysis of the two sites combined. When treated individually there was no significant correlations between shaping and specific gravity. When the combined data were analyzed, the regression coefficient was highly significant. Although this analysis indicates that an increase in specific gravity gave better shaping results, the correlation coefficient shows that specific gravity accounts for only 12 percent of the variability observed.

Davis (6) in his studies of machining properties of North American woods found that where there was any considerable difference in the specific gravity of different pieces of the same wood, the heavier pieces gave better shaping results. Our analysis shows a similar trend, but the very low correlation coefficient does not make this very meaningful.

Relationship between growth rate and specific gravity

The relationship between growth rate and specific gravity of diffuse porous hardwoods has been reported. Rapid growth has been associated with a decrease in specific gravity (22), increased specific gravity (13), no relation (5,12,16), or with increased specific gravity in some species and decreased specific gravity in others (11). Plantation-grown bigleaf mahogany in Puerto Rico has been reported to increase in specific gravity with increased growth rate (3).

To explore the effect of growth rate on specific gravity, linear regression analyses were made for the material from Río Abajo and Harvey plantations. The 12 sample trees from each site had a dbh range of about 8 to 18 inches (see table 1). In both plantations the regressions were not significant, that is, the specific gravity of samples from fast-growing mahogany stems was not significantly different from slow-growing stems.

Relationship between growth rate and machining quality

Linear regression analyses were also made to determine whether or not growth rate has an effect on shaping and planing qualities. Since these are evenaged stands, growth was expressed as dbh. Mahogany from the three plantations in Puerto Rico and from St. Croix were selected for this analysis.

Only the Bisley mahogany showed highly significant correlation between machining defect ratings and growth rate. However, correlation coefficients of only 1 to 4 percent emphasize that growth rate is not a determining factor for machining quality of mahogany.

These attempts to define some variables that may be related to the machining quality of mahogany are preliminary and exploratory. It is obvious that important characteristics have yet to be described. Studies are now under way to determine what anatomical properties can be used to predict the machinability of wood.

CONCLUSIONS

1. Small-leaf mahogany from St. Croix, U.S. Virgin Islands is superior in shaping and planing to all other woods tested in this study.

2. In shaping quality, bigleaf mahogany from the Río Abajo plantation and the hybrid from the Harvey plantation compare favorably. They rated better than mahogany imported from Mexico, Perú, Honduras, and the plantation-grown wood from Bisley.

3. In general, all the woods performed well in planing. The plantation-grown mahogany from Río Abajo, Harvey, and Bisley ranked better than the forest-grown mahogany from Perú and Honduras, but not as well as the wood from Mexico.

4. Local plantation-grown teak rates as well as forest-grown teak from Burma in shaping. Planing defects were not significantly different except for torn grain which was more severe in the plantation wood.

5. For two bigleaf mahogany plantations, regression analyses of shaping quality and specific gravity show highly significant correlations. However, the correlation coefficient is very low.

6. Relationships between growth rate and machining quality of the various mahoganies, except for the Bisley material, are generally not significant. Where significance was found, correlation coefficients were of low order.

7. Fast-growing plantation mahogany is not significantly different in density from slow-growing stems.

LITERATURE CITED

(1) Anonymous
1961. Mechanical properties of natural and plantation teak. FAO Newsletter, Oct. 25, 1961.

(2) Briscoe, C.B., and Lamb, F.B.
1962. Leaf size in *Swietenia*. Carib. Forester 23:112-115.

(3) ________, Harris, J.B., and Wyckoff, D.
1963. Variation of specific gravity in plantation-grown trees of bigleaf mahogany. Carib. Forester 24:67-74.

(4) Brown, H.P., Panshin, A.J., and Forsaith, C.C.
1949. Textbook of wood technology, Vol.I, McGraw-Hill Book Co., Inc., New York, 652 pp.

(5) Chudnoff, M.
1961. The physical and mechanical properties of *Eucalyptus camaldulensis* Dehn. The Nat. and Univ. Inst. of Agr. Bul. 66, Beit Dagan, Israel, 39 pp.

(6) Davis, E.M.
1962. Machining and related characteristics of United States hardwoods. U.S. Dept. Agr., Tech. Bul. No. 1267, 68 pp.

(7) Dickenson, F.E., Hess, R.W., and Wangaard, F.F.
1949. Properties and uses of tropical woods, I., Trop. Woods No. 95:1-145.

(8) Elliot, C.S.
1961. Five years progress in technology and utilization. Rpt. & Docum. 2d World Eucalyptus Conf., Sao Paulo, Brazil, Vol. 2, pp. 1.085-1097.

(9) Gerhards, C.C.
1965. Physical and mechanical properties of saligna eucalyptus grown in Hawaii. U.S. Forest Serv. Forest Prod. Lab. Res. Paper FPL-23, 12 pp.

(10) ________
1966. Physical and mechanical properties of blackbutt eucalyptus grown in Hawaii. U.S. Forest Serv. Forest Prod. Lab. Res. Paper FPL-65, 8 pp.

(11) Ghosh, S.S., Rao, K.R., and Purkayastha, S.K.
1958. Variation in structure and quality of some Indian timbers in relation to growth. Indian Forester 84:341-344.

(12) Gohre, K., and Gotze, H.
1956. Investigation of the density of red beech wood. Arch. Forstw. 5:716-748.

(13) Grossler, W.
1943. Wood technological investigations of high-mountain beech. Holz Roh-u. Werkstoff 1:81-86.

(14) Koch, P.
1964. Wood machining processes. The Ronald Press Co., New York, 530 pp.

(15) Lamb, F.B.
1966. Mahogany of tropical America - its ecology and management. Univ. Mich. Press, Ann Arbor, 220 pp.

(16) Lenz, O.
1954. The wood of a few poplars cultivated in Switzerland. Mitt. Schweiz. Anst. Forstl. VersWes. 30:9-61.

(17) Longwood, F.R.
1961. Puerto Rican woods : their machining, seasoning, and related characteristics. U.S. Dept. Agr., Agr. Handb. 205, 98 pp.

(18) ________
1962. Present and potential commercial timbers of the Caribbean. U.S. Dept. Agr., Agr. Handb. 207, 167 pp.

(19) Pearson, R.S.
1911. Note on the relative strength of natural and plantation grown teak in Burma. Indian Forest Bul. No. 3, 9 pp.

(20) Puerto Rico Planning Board
1964. 1964 External Trade Statistics, 324 pp.

(21) Sono, P., and Rativanich, T.
1964. Comparative study on properties of plantation and natural grown teak in Thailand. Thai. Forestry Bul. (Bot.) No. R65, 6 pp.

(22) Susmel, L.
1953. The specific gravity of Eucalyptus rostrata Schlecht. wood from the Pontine Campagna. Ital. for. mont. 8:222-227.

(23) Wangaard, F.F.
1950. The mechanical properties of wood. John Wiley, New York, 377 pp.

APPENDIX

Table 4.--Ratings for individual planing defects

Species and Source	Average Defect Ratings[1/]			
	Fuzzy grain	Torn grain	Chip marks	Raised grain
Mahogany				
Forest-grown				
Mexico	1.7	1.4	1.2	1.1
Perú	2.0	2.5	1.1	1.1
Honduras	2.0	2.0	1.5	1.1
Plantation-grown				
St. Croix[2/]	1.0	1.6	1.0	1.0
Harvey (hybrid)	1.2	2.0	1.2	1.1
Río Abajo	1.4	2.0	1.2	1.0
Bisley	1.6	1.6	1.5	1.1
Teak				
Forest-grown				
Burma	1.0	1.3	1.0	1.0
Plantation-grown				
Patillas	1.1	1.8	1.0	1.0
Río Abajo	1.1	2.1	1.0	1.0
Temperate zone wood				
Birch (Canada)	1.2	2.5	1.1	1.0

1/ Based on 1-5 scale; with 1 - defect free and 5 - very poor.
2/ Established by natural seeding from earlier plantings of *Swietenia mahagoni* Jacq.

Table 5.--Comparison of planing results - analysis of variance (fuzzy grain and raised grain)

Species and Source	Mahogany (Mexico)	Mahogany (Peru)	Mahogany (Honduras)	Mahogany (St.Croix)	Mahogany (Harvey)	Mahogany (R.Abajo)	Mahogany (Bisley)	Teak (Burma)	Teak (Patillas)	Teak (R.Abajo)	Birch (Canada)
Mahogany (Mexico)		--1/	--	--	--	--	--	--	--	--	--
Mahogany (Peru)	2/x		--	--	--	--	--	--	--	--	--
Mahogany (Honduras)	3/xx	--		--	--	--	--	--	--	--	--
Mahogany (St. Croix)	xx	xx	xx		--	--	--	--	--	--	--
Mahogany (Harvey)	x	xx	xx	--		--	--	--	--	--	--
Mahogany (Rio Abajo)	--	xx	xx	--	--		--	--	--	--	--
Mahogany (Bisley)	xx	xx	xx	xx	x	--		--	--	--	--
Teak (Burma)	xx	xx	xx	--	--	--	xx		--	--	--
Teak (Patillas)	xx	xx	xx	--	--	--	xx	--		--	--
Teak (Rio Abajo)	xx	xx	xx	--	--	--	xx	--	--		--
Birch (Canada)	x	xx	xx	--	--	--	x	--	--	--	

FUZZY GRAIN (lower left) — RAISED GRAIN (upper right)

1/ -- = difference not significant.
2/ x = significant 5% level.
3/ xx = significant 1% level.

xx (upper right) — x in upper right favors wood listed at top.

xx (lower left) — x in lower left favors wood listed in side column.

Table 6.--Comparison of planing results - analysis of variance (torn grain and chip marks)

Species and Source	Mahogany (Mexico)	Mahogany (Peru)	Mahogany (Honduras)	Mahogany (St.Croix)	Mahogany (Harvey)	Mahogany (R.Abajo)	Mahogany (Bisley)	Teak (Burma)	Teak (Patillas)	Teak (R. Abajo)	Birch (Canada)
Mahogany (Mexico)		-- 1/	xx 2/	--	--	--	xx	--	--	--	--
Mahogany (Peru)	xx		xx	--	--	--	xx	--	--	--	--
Mahogany (Honduras)	xx	xx		xx	3/ x	x	--	xx	xx	xx	xx
Mahogany (St. Croix)	--	xx	x		--	--	xx	--	--	--	--
Mahogany (Harvey)	x	x	--	--		--	x	--	--	--	--
Mahogany (Rio Abajo)	x	x	--	--	--		x	--	--	--	--
Mahogany (Bisley)	--	xx	xx	--	x	x		xx	xx	xx	xx
Teak (Burma)	--	xx	xx	xx	xx	x	--		--	--	--
Teak (Patillas)	--	xx	--	--	--	--	--	x		--	--
Teak (Rio Abajo)	xx	--	--	x	--	--	xx	xx	--		--
Birch (Canada)	xx	--	x	xx	--	--	xx	--	xx	--	

CHIP MARKS

TORN GRAIN

1/ -- = difference not significant.
2/ xx = significant 1% level.
3/ x = significant 5% level.

xx — x in upper right favors wood listed at top

xx — x in lower left favors wood listed in side column

Table 7.--Ratings for individual shaping defects

Species and Source	Average Defect Ratings 1/			
	Torn end grain	Fuzzy end grain	Torn side grain	Fuzzy side grain
Mahogany				
Forest-grown				
Mexico	2.3	2.8	3.1	2.1
Peru	2.3	2.6	3.8	2.2
Honduras	3.0	3.2	3.4	2.5
Plantation-grown				
St. Croix 2/	1.0	1.4	1.6	1.1
Harvey (hybrid)	1.4	1.7	2.2	1.1
Rio Abajo	1.1	1.9	2.4	1.8
Bisley	3.1	3.8	3.7	2.8
Teak				
Forest-grown				
Burma	1.0	1.2	2.1	1.0
Plantation-grown				
Patillas	1.1	1.4	2.5	1.5
Rio Abajo	1.2	1.5	3.0	1.2
Temperate zone woods				
Birch (Canada)	1.0	1.7	2.3	1.4
Sweetgum (U.S.A.)	1.5	1.3	3.3	1.1

1/ Based on 1-5 scale; with 1 - defect free and 5 - very poor.
2/ Established by natural seeding from earlier plantings of *Swietenia mahagoni* Jacq.

Table 8.--Comparison of shaping results - analysis of variance (torn side grain and fuzzy side grain)

Species and Source	Mahogany (Mexico)	Mahogany (Peru)	Mahogany (Honduras)	Mahogany (St.Croix)	Mahogany (Harvey)	Mahogany (R. Abajo)	Mahogany (Bisley)	Teak (Burma)	Teak (Patillas)	Teak (R. Abajo)	Birch (Canada)	Sweetgum (U.S.A.)
Mahogany (Mexico)		-- 1/	x 2/	3/ xx	xx	--	xx	xx	x	xx	x	xx
Mahogany (Peru)	xx		--	xx	xx	x	xx	xx	x	xx	xx	xx
Mahogany (Honduras)	--	xx		xx	xx	xx	xx	xx	xx	xx	xx	xx
Mahogany (St. Croix)	xx	xx	xx		--	xx	xx	--	--	--	--	--
Mahogany (Harvey)	xx	xx	xx	--		--	xx	--	--	--	--	--
Mahogany (Rio Abajo)	xx	xx	xx	x	--		xx	xx	--	x	--	xx
Mahogany (Bisley)	xx	--	xx	xx	xx	xx		xx	xx	xx	xx	xx
Teak (Burma)	xx	xx	xx	--	--	--	xx		--	--	--	--
Teak (Patillas)	x	xx	xx	x	--	--	xx	--		--	--	--
Teak (Rio Abajo)	--	xx	--	xx	xx	--	x	--	--		--	--
Birch (Canada)	x	xx	xx	--	--	--	xx	--	--	--		--
Sweetgum (U.S.A.)	--	--	--	xx	xx	xx	--	--	--	--	--	

TORN SIDE GRAIN

FUZZY SIDE GRAIN

1/ -- = difference not significant.
2/ x = significant 5% level.
3/ xx = significant 1% level.

xx — x in upper right favors wood listed at top

xx — x in lower left favors wood listed in side column

Table 9.--Comparison of shaping results - analysis of variance (torn end grain and fuzzy end grain)

Species and Source	Mahogany (Mexico)	Mahogany (Peru)	Mahogany (Honduras)	Mahogany (St.Croix)	Mahogany (Harvey)	Mahogany (R. Abajo)	Mahogany (Bisley)	Teak (Burma)	Teak (Patillas)	Teak (R. Abajo)	Birch (Canada)	Sweetgum (U.S.A.)
Mahogany (Mexico)		-- [1]	xx [2]	xx	xx	xx	xx	xx	xx	xx	xx	[3] x
Mahogany (Peru)	--		xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
Mahogany (Honduras)	xx	xx		xx	xx	xx	xx	xx	xx	xx	xx	xx
Mahogany (St. Croix)	xx	xx	xx		--	x	xx	--	--	--	--	--
Mahogany (Harvey)	xx	xx	xx	xx		xx	xx	x	--	--	--	--
Mahogany (Rio Abajo)	xx	xx	xx	--	x		xx	xx	x	x	--	xx
Mahogany (Bisley)	xx	--	--	xx	xx	xx		xx	xx	xx	xx	xx
Teak (Burma)	xx	xx	xx	--	--	--	xx		--	--	--	--
Teak (Patillas)	xx	xx	xx	--	--	--	xx	--		--	--	--
Teak (Rio Abajo)	xx	xx	xx	--	--	--	xx	--	--		--	--
Birch (Canada)	xx	xx	xx	--	--	--	xx	--	--	--		--
Sweetgum (U.S.A.)	x	x	xx	--	--	--	xx	--	--	--	--	

FUZZY END GRAIN

TORN END GRAIN

1/ -- = difference not significant.
2/ xx = significant 1% level.
3/ x = significant 5% level.

xx — x in upper right favors wood listed at top

xx — x in lower left favors wood listed in side column

Maldonado, E.D., and Boone, R.S.
1968. Shaping and planing characteristics of plantation-grown mahogany and teak. Inst. Trop. Forestry, U. S. Forest Serv. Res. Paper ITF-7.

Shaping and planing characteristics of Puerto Rico plantation-grown mahogany and teak are reported. Included is small-leaf (West Indies) mahogany from the U.S.Virgin Islands. Forest-grown mahogany from Mexico, Honduras, and Perú; teak from Burma; sweetgum from the U.S.A.; and birch from Canada were also tested for comparison.

The small-leaf mahogany proved superior in shaping and planing properties to those of all other woods tested. In shaping, two mahogany plantations and both teak plantations yielded wood that rated as good as the imported forest-grown material. In general all the woods performed well in planing. Shaping quality is only weakly correlated with specific gravity and growth rate.

Maldonado, E.D., and Boone, R.S.
1968. Shaping and planing characteristics of plantation-grown mahogany and teak. Inst. Trop. Forestry, U. S. Forest Serv. Res. Paper ITF-7.

Shaping and planing characteristics of Puerto Rico plantation-grown mahogany and teak are reported. Included is small-leaf (West Indies) mahogany from the U.S.Virgin Islands. Forest-grown mahogany from Mexico, Honduras, and Perú; teak from Burma; sweetgum from the U.S.A.; and birch from Canada were also tested for comparison.

The small-leaf mahogany proved superior in shaping and planing properties to those of all other woods tested. In shaping, two mahogany plantations and both teak plantations yielded wood that rated as good as the imported forest-grown material. In general all the woods performed well in planing. Shaping quality is only weakly correlated with specific gravity and growth rate.

Maldonado, E.D., and Boone, R.S.
1968. Shaping and planing characteristics of plantation-grown mahogany and teak. Inst. Trop. Forestry, U. S. Forest Serv. Res. Paper ITF-7.

Shaping and planing characteristics of Puerto Rico plantation-grown mahogany and teak are reported. Included is small-leaf (West Indies) mahogany from the U.S.Virgin Islands. Forest-grown mahogany from Mexico, Honduras, and Perú; teak from Burma; sweetgum from the U.S.A.; and birch from Canada were also tested for comparison.

The small-leaf mahogany proved superior in shaping and planing properties to those of all other woods tested. In shaping, two mahogany plantations and both teak plantations yielded wood that rated as good as the imported forest-grown material. In general all the woods performed well in planing. Shaping quality is only weakly correlated with specific gravity and growth rate.

Maldonado, E.D., and Boone, R.S.
1968. Shaping and planing characteristics of plantation-grown mahogany and teak. Inst. Trop. Forestry, U. S. Forest Serv. Res. Paper ITF-7.

Shaping and planing characteristics of Puerto Rico plantation-grown mahogany and teak are reported. Included is small-leaf (West Indies) mahogany from the U.S.Virgin Islands. Forest-grown mahogany from Mexico, Honduras, and Perú; teak from Burma; sweetgum from the U.S.A.; and birch from Canada were also tested for comparison.

The small-leaf mahogany proved superior in shaping and planing properties to those of all other woods tested. In shaping, two mahogany plantations and both teak plantations yielded wood that rated as good as the imported forest-grown material. In general all the woods performed well in planing. Shaping quality is only weakly correlated with specific gravity and growth rate.